CHAPTER 9

SHAPERS, PLANERS, AND ENGRAVERS

CHAPTER LEARNING OBJECTIVES

Upon completing this chapter, you should be able to do the following:

- *Identify and explain the use of shapers.*
- *Identlfy and explain the use of planers.*
- *Explain the use of pantographs.*

In this chapter we will discuss the major types of shapers, planers, and pantographs (engravers), and their individual components, cutters, and operating principles and procedures. A shaper has a reciprocating single-edged cutting tool that removes metal from the work as the work is fed into the tool. A planer operates on a similar principle except that the work reciprocates, and the tool is fed into the work. A pantograph is used primarily to engrave letters and designs on any type of material. The material can be flat, concave, convex, or spherical.

As with any shop equipment you must observe all posted safety precautions. Review safety precautions in your equipment operators manual and any chapters of *Navy Occupational Safety and Health (NAVOSH) Program Manual for Forces Afloat,* OPNAV Instruction 5100.19B, that pertain to the equipment.

SHAPERS

A shaper has a reciprocating ram that carries a cutting tool. The tool cuts only on the forward stroke of the ram. The work is held in a vise or on the worktable, which moves at a right angle to the line of motion of the ram, permitting the cuts to progress across the surface being machined. A shaper is identified by the maximum size of a cube it can machine; thus, a 24-inch shaper will machine a 24-inch cube.

HORIZONTAL SHAPERS

There are three distinct types of horizontal shapers: crank, geared, and hydraulic. The type depends on how the ram receives motion to produce its own reciprocating motion. In a crank shaper the ram is moved by a rocker arm that is driven by an adjustable crankpin secured to the main driving gear. Quick return of the ram is a feature of a crank shaper. In a geared shaper, the ram is moved by a spur gear that meshes with a rack secured to the bottom of the ram. In a hydraulic shaper, the ram is moved by a hydraulic cylinder whose piston rod is attached to the bottom of the ram. Uniform tool pressure, smooth drive, and smooth work are features of the hydraulic shaper.

There are many different makes of shapers, but the essential parts and controls are the same on all. When you learn how to operate one make of shaper, you will not have any trouble learning to operate another make. Figure 9-1 is an illustration of a crank shaper found in shops in many Navy ships and shore repair facilities.

Shaper Components

This section covers the construction and operation of the main components. They are the main frame assembly, drive assembly, crossrail assembly, toolhead assembly, and table feed mechanism. (See fig. 9-2.)

MAIN FRAME ASSEMBLY.—The main frame assembly consists of the base and the column. The base houses the lubricating pump and sump, which provide forced lubrication to the machine. The column contains the drive and feed actuating mechanisms. A dovetail slide is machined on top of the column to receive the ram. Vertical flat ways are machined on the front of the column to receive the crossrail.

DRIVE ASSEMBLY.—The drive assembly consists of the ram and the crank assembly. These parts convert the rotary motion of the drive pinion to the reciprocating motion of the ram. By using the

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Figure 9-1.—Standard shaper.

adjustments provided, you can increase or decrease the length of stroke of the ram. You also can position the ram so the stroke is in the proper area in relation to the work.

You can adjust the **CRANKPIN,** which is mounted on the crank gear, from the center of the crank gear outward. The sliding block fits over the crankpin and has a freesliding fit in the rocker arm. If you center the crankpin (and therefore the sliding block) on the axis of the crank gear, the rocker arm will not move when the crank gear turns. But, if you set the crankpin off center by turning the stroke adjusting screw, any motion of the crank gear will cause the rocker arm to move. This motion is transferred to the ram through the ram linkage and starts the reciprocating motion of the ram. The distance the crankpin is set off center determines the length of stroke of the tool.

To position the ram, turn the ram positioning screw until the ram is placed properly with respect to the work Specific procedures for positioning the ram and setting the stroke are in the manufacturer's technical manual for the specific machines you are using.

CROSSRAIL ASSEMBLY.—The crossrail assembly includes the crossrail, the crossfeed screw, the table, and the table support bracket (foot). (See fig. 9-1.) The crossrail slides on the vertical ways on the front of the shaper column. The crossrail apron (to which the worktable is secured) slides on horizontal ways on the crossrail. The crossfeed screw engages in a mating nut, which is secured to the back of the apron. You can turn the screw either manually or by power to move the table horizontally.

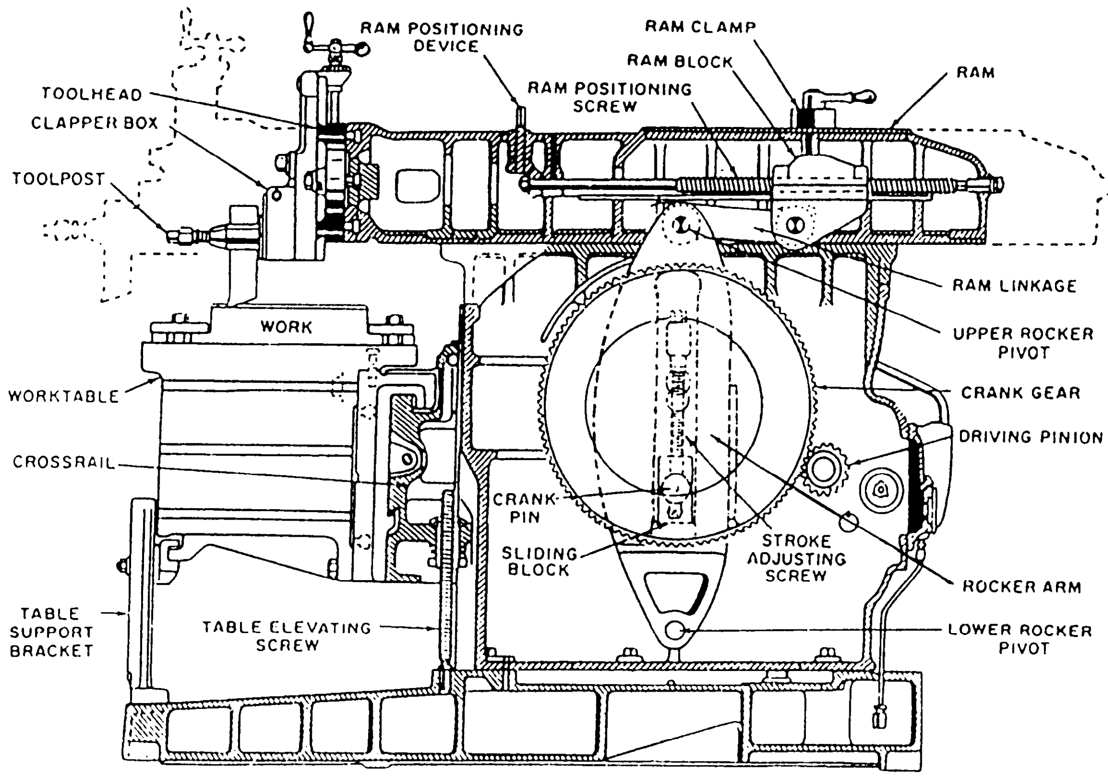

Figure 9-2.—Cross-sectional view of a crank-type shaper.

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Figure 9-3.—Swiveled and tilted table.

The worktable may be plain or universal, as shown in figure 9-3. Some universal tables can be swiveled only right or left, away from the perpendicular; others may be tilted fore or aft at small angles to the ram. T-slots on the worktables are for mounting the work or work-holding devices. A table support bracket (foot) holds the worktable and can be adjusted to the height required. The bracket slides along a flat surface on the base as the table moves horizontally. The table can be adjusted vertically by the table elevating screw (fig. 9-2).

TABLE FEED MECHANISM.—The table feed mechanism (fig. 9-4) consists of a ratchet wheel and

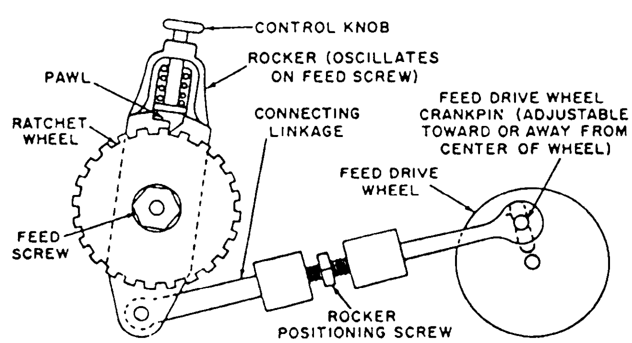

Figure 9-4.—Mechanical table feed mechanism.

pawl, a rocker, and a feed drive wheel. The feed drive wheel is driven by the main crank. It operates similarly to the ram drive mechanism and converts rotary motion to reciprocating motion. As the feed drive wheel rotates, the crankpin (which can be adjusted off center) causes the rocker to oscillate. The straight face of the pawl pushes on the back side of a tooth on the ratchet wheel, turning the ratchet wheel and the feed screw. The back face of the pawl is cut at an angle to ride over one or more teeth as it is rocked in the opposite direction. To change the direction of feed, lift the pawl and rotate it one-half turn. To increase the rate of feed, increase the distance between the feed drive wheel crankpin and the center of the feed drive wheel.

The ratchet wheel and pawl method of feeding crank-type shapers has been used for many years. Relatively late model machines still use similar principles. Pocedures used to operate feed mechanisms vary, so consult manufacturers' technical manuals for explicit instructions.

TOOLHEAD ASSEMBLY.—The toolhead assembly consists of the toolslide, the downfeed mechanism, the clapper box, the clapper head, and the toolpost at the forward end of the ram. You can swivel the entire assembly and set it at any angle not exceeding 50° on either side of the vertical. Raise or lower the toolhead by hand feed to make vertical cuts on the work When you make vertical or angular cuts, swivel the clapper box away from the surface to be machined (fig. 9-5); otherwise, the tool will dig into the work on the return stroke.

Vises and Toolholders

Vises and toolholders are not integral parts of the shaper as are the previously mentioned assemblies, so we will discuss them separately in the next paragraphs.

VISE.—The shaper vise is a sturdy mechanism secured to the table by T-bolts. It has two jaws, one stationary and the other movable, that can be drawn together by a screw (fig. 9-3). These jaws are longer and deeper than most similar devices to accommodate large work, and most of them have hardened steel jaws ground in place. Some shapers use a universal vise that can be swiveled in a horizontal plane from 0° to 180°. However, the jaws are usually set either parallel to, or at a right angle to, the stroke of the ram. Before you start work, be sure the vise is free from any obstruction that might keep the work from seating properly, and remove burrs, rough edges, and chips left from previous machining.

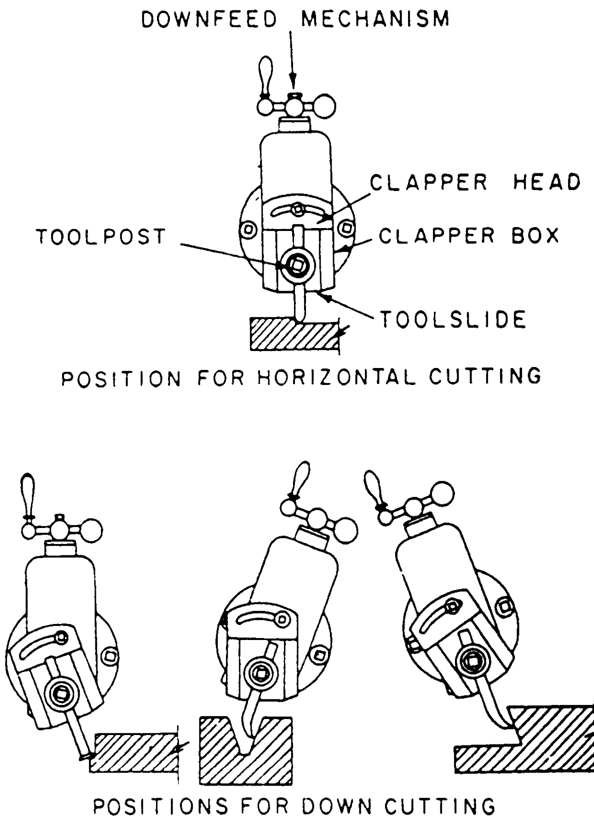

Figure 9-5.—Toolhead assembly in various positions.

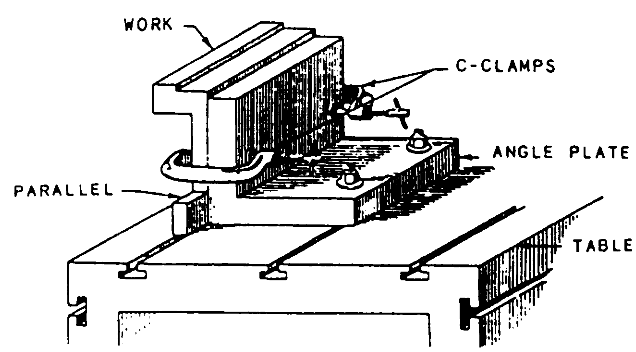

Figure 9-6.—Methods of holding and clamping.

You can set the work on parallels so the surface to be cut is above the top of the vise. You can use shaper holddowns to hold the work between the jaws of the vise. If the work is larger than the vise will hold, you can clamp it directly to the top or side of the machine table. When you must rotate work too large or awkward for a swivel vise, you can clamp it to a rotary table. You also may use V-blocks, angle plates, and C-clamps to mount work on shaper tables (fig. 9-6).

TOOLHOLDERS.—Various types of toolholders made to hold interchangeable tool bits are used to a great

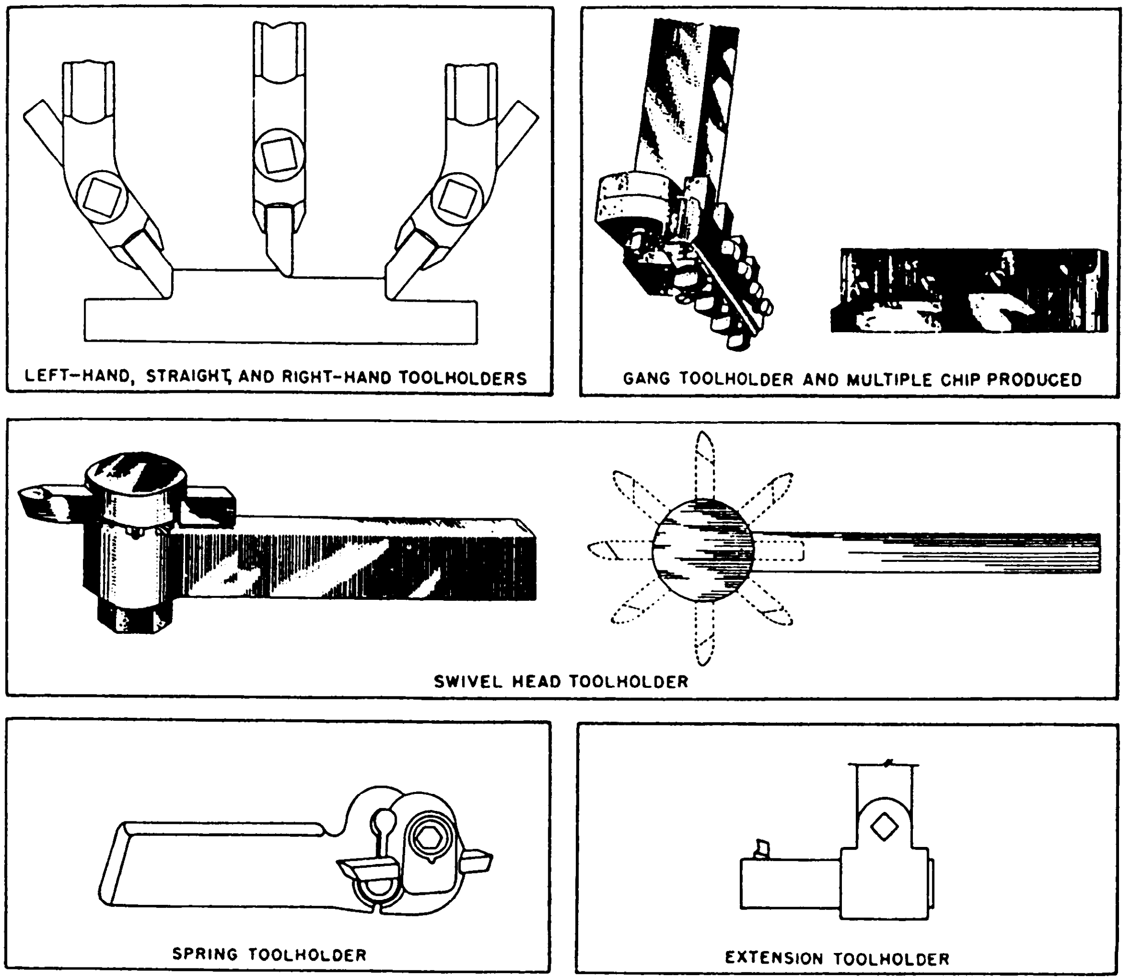

Figure 9-7.—Toolholders.

extent in planer and shaper work Tool bits are available in different sizes and are hardened and cut to standard lengths to fit the toolholders. The toolholders that you will most commonly use are described in the following list and shown in figure 9-7:

1. Right-hand, straight, and left-hand toolholders used in most common shaper and planer operations.

2. Gang toolholders especially adapted to surface large castings. With a gang toolholder, you make multiple cuts with each forward stroke of the shaper. Each tool takes a light cut and there is less tendency to "break out" at the end of a cut.

3. Swivel head toolholders are universal, patented holders that you can adjust to place the tool in various radial positions. This feature allows you to convert the swivel head toolholder to a straight, right-hand, or left-hand holder at will.

4. Spring toolholders have a rigid, U-shaped spring that lets the holder cap absorb a considerable amount of vibration. This toolholder is particularly good for use with formed cutters, which have a tendency to chatter and dig into the work.

5. Extension toolholders are adapted to cut internal keyways, splines, and grooves on the shaper. You can adjust the extension arm of the holder to change the exposed length and the radial position of the tool.

Chapter 5 contains procedures used to grind shaper and planer tool bits for various operations.

Operations

Before beginning any job on the shaper, you should thoroughly study and understand the blueprint or drawing from which you are to work. In addition, you should take the following precautions:

- Make certain that the shaper is well oiled.
- Clean away **ALL** chips from previous work.

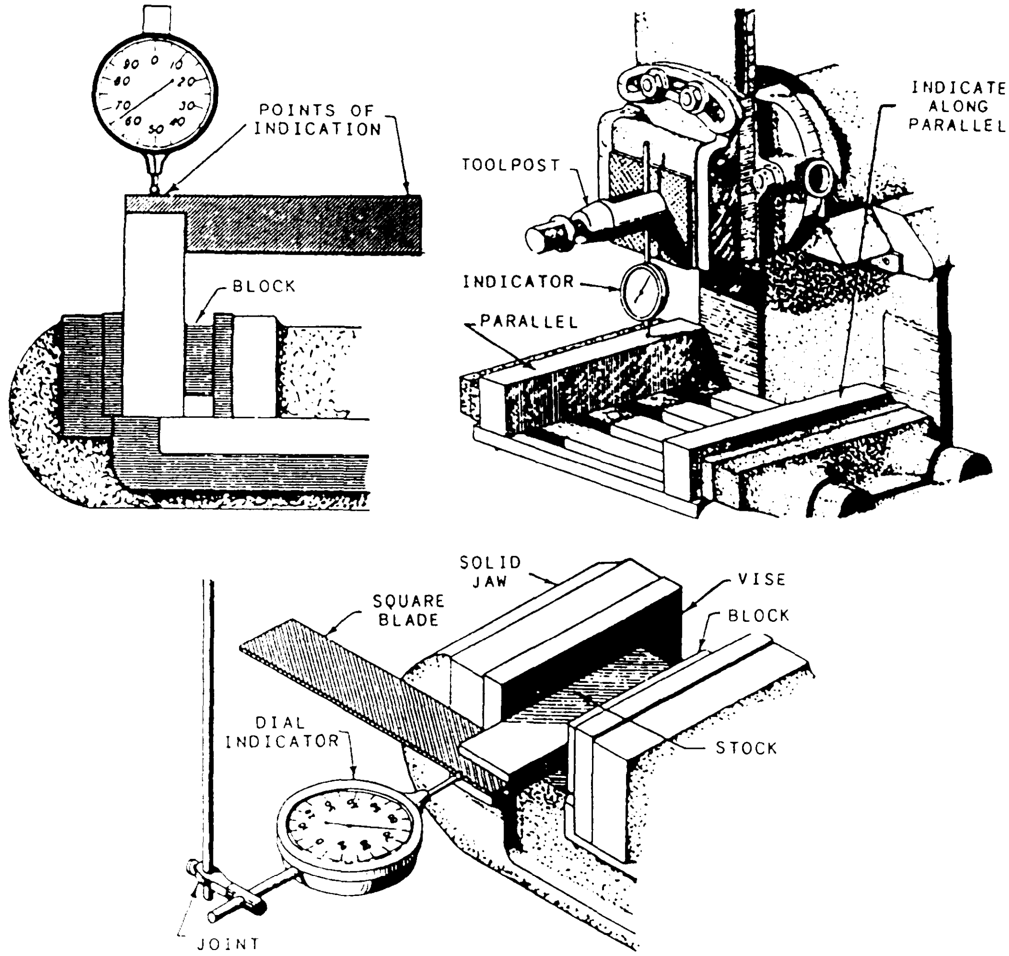

Figure 9-8.—Squaring the table and the vise.

- Be sure the cutting tool is set properly; otherwise, the tool bit will chatter. Set the toolholder so the tool bit does not extend more than about 2 inches below the clapper box.
- Be sure the piece of work is held rigidly in the vise to prevent chatter. You can seat the work by tapping it with a babbitt hammer.
- Test the table to see if it is level and square. Make these tests with a dial indicator and a machinist's square, as shown in figure 9-8. If either the table or the vise is off parallel, check for dirt under the vise or improper adjustment of the table support bracket.
- Adjust the ram for length of stroke and position. The cutting tool should travel 1/8 to 1/4 inch past the edge of the work on the forward stroke and 3/4 to 7/8 inch behind the rear edge of the work on the return stroke.

SPEEDS AND FEEDS.—You will set up the shaper to cut a certain material similar to the way you set up other machine tools, such as drill presses and lathes. First, determine the approximate required cutting speed, then determine and set the necessary machine speed to produce your desired cutting speed. On all of the machine tools we discussed in the previous chapters, cutting speed was directly related to the speed (rpm) of the machine's spindle. You could determine what spindle rpm to set by using one formula for all brands of a particular type of machine. The setup for a shaper is slightly different. You still relate cutting speed to machine speed through a formula, but the formula depends on the brand of machine that you operate. This is because some manufacturers use a slightly different formula to compute cutting speed than others. To determine the correct formula for your machine, consult the operator's manual provided by the manufacturer.

The following discussion explains basically how the operation of a shaper differs from the operation of other machine tools. It also explains how to determine

Table 9-1.—Recommended Cutting Speeds for Various Metals

Type of metal	Cutting speed (feet per minute)			
	Carbon steel tools		High-speed steel tools	
	Roughing	Finishing	Roughing	Finishing
Cast iron	30	20	60	40
Mild steel	25	40	50	80
Tool steel	20	30	40	60
Brass, Bronze	75	100	150	200
Aluminum	75	100	150	200

the cutting speeds and related machine speeds for a Cincinnati shaper.

When you determine the speed of the shaper required to produce a particular cutting speed, you must account for the shaper's reciprocating action. This is because the tool only cuts on the forward stroke of the ram. In most shapers the time required for the cutting stroke is 1 1/2 times that required for the return stroke. This means that in any one cycle of ram action the cutting stroke consumes 3/5 of the time and the return stroke 2/5 of the time. The formula used to determine machine strokes contains a constant that accounts for the time consumed by the cutting stroke.

To determine a cutting stroke value to set on the shaper speed indicator, first select a recommended cutting speed for the material you plan to shape from a chart such as the one shown in table 9-1.

Next, determine the ram stroke speed by using the following formula (remember, your machine may require a slightly different formula):

$$SPM = \frac{CS}{0.14 \times LOS}$$

Where: SPM = strokes of the ram per minute

CS = cutting speed in feet per minute

LOS = length of stroke in inches

0.14 = constant that accounts for partial ram cycle time and that converts inches to feet

Then, set the number of strokes per minute on the shaper by using the gear shift lever. A speed (strokes) indicator plate shows the positions of the lever for a variety of speeds. Take a few trial cuts and adjust the ram speed as necessary until you obtain the desired cut on the work.

If after you have adjusted the ram speed, you want to know the exact cutting speed of the tool, use the following formula:

$$CS = SPM \times LOS \times 0.14$$

The speed of the shaper is regulated by the gear shift lever. The change gear box, located on the operator's side of the shaper, lets you change the speed of the ram and cutting tool according to the length of the work and the hardness of the metal. When the driving gear is at a constant speed, the ram will make the same number of strokes per minute regardless of whether the stroke is 4 inches or 12 inches. Therefore, to maintain the same cutting speed, the cutting tool must make three times as many strokes for the 4-inch cut as it does for the 12-inch cut.

Horizontal feed rates of up to approximately 0.170 inch per stroke are available on most shapers. There are no hard and fast rules for selecting a specific feed rate; you must rely on experience and common sense. Generally, to make roughing cuts on rigidly held work, set the feed as heavy as the machine will allow. For less rigid setups and for finishing, use light feeds and small depths of cut. It is best to start with a relatively light feed and increase it until you reach a desirable feed rate.

SHAPING A RECTANGULAR BLOCK.—An accurately machined rectangular block has square corners and opposite surfaces that are parallel to each other. In this discussion, faces are the surfaces of the block that have the largest surface area; the ends are the surfaces that limit the length of the block; and the sides are the surfaces that limit the width of the block.

You can machine a rectangular block in four setups if you use a shaper vise. Machine one face and an end in the first setup. Machine the opposite face and end in the second setup. Then, machine the sides in two similar but separate setups. Align the vise jaws at right angles to the ram in both setups.

To machine a rectangular block from a rough casting, use the following sequence of operations:

1. Clamp the casting in the vise so a face is horizontally level and slightly above the top of the vise jaws. Allow one end to extend out of the side of the vise jaws enough so you can take a cut on the end without unclamping the casting. Now feed the cutting tool down to the required depth and take a horizontal cut across the face. After you have machined the face, readjust the cutting tool so it will cut across the surface of the end that extends from the vise. Use the horizontal motion of the ram and the vertical adjustment of the toolhead to move the tool across and down the surface of the end. When you have machined the end, check to be sure it is square with the machined face. If it is not square, adjust the toolhead swivel to correct the inaccuracy and take another light finishing cut down the end.

2. To machine the second face and end, turn the block over and set the previously machined face on parallels (similar to the method used in step 1). Insert small strips of paper between each corner of the block and the parallels. Clamp the block in the vise and USC a soft-face mallet to tap the block down solidly on the parallels. When the block is held securely in the vise, machine the second face and end to the correct thickness and length dimensions of the block.

3. To machine a side, open the vise jaws so the jaws can be clamped on the ends of the block. Now set the block on parallels in the vise with the side extending out of the jaws enough to permit a cut using the downfeed mechanism. Adjust the ram for length of stroke and for position to machine the side and make the cut.

4. Set up and machine the other side as described in step 3.

SHAPING ANGULAR SURFACES.—You may use one of two methods to machine angular surfaces. For steep angles, such as on V-blocks, mount the work horizontally and swivel the toolhead to the desired angle. For small angles of taper, such as on wedges, mount the work on the table at the desired angle from the horizontal, or you can tilt the table if the shaper has a universal table.

To machine a steep angle using the toolhead swiveled to the proper angle, use the following sequence of operations:

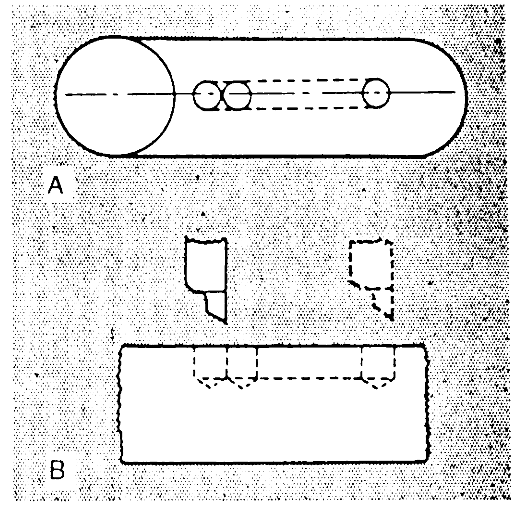

Figure 9-9.—Cutting a keyway in the middle of a shaft.

1. Set up the work as you would to machine a flat surface parallel with the table.

2. Swivel the toolhead (fig. 9-5) to the required angle. (Swivel the clapper box in the opposite direction.)

3. Start the machine and, using the manual feed wheel on the toolhead, feed the tool down across the workpiece. Use the horizontal feed control to feed the work into the tool and to control the depth of cut (thickness of the chip). (Because the tool is fed manually, be careful to feed the tool toward the work only during the return stroke.)

4. Set up and machine the other side as described in step 3.

SHAPING KEYWAYS IN SHAFTS.—Occasionally, you may use a shaper to cut a keyway in a shaft. Normally, you will lay out the length and width of the keyway on the circumference of the shaft. A centerline laid out along the length of the shaft and across the end of the shaft will make the setup easier (fig. 9-9, view A). Figure 9-9 also shows holes of the same diameter as the keyway width and slightly deeper than the key drilled into the shaft. These holes are required to provide tool clearance at the beginning and end of the cutting stroke. The holes shown in figure 9-9 are located to cut a blind keyway (not ending at the end of a shaft). If the kcyway extends to the end of the shaft, only one hole is necessary.

To cut a keyway in a shaft, use the following sequence of operations:

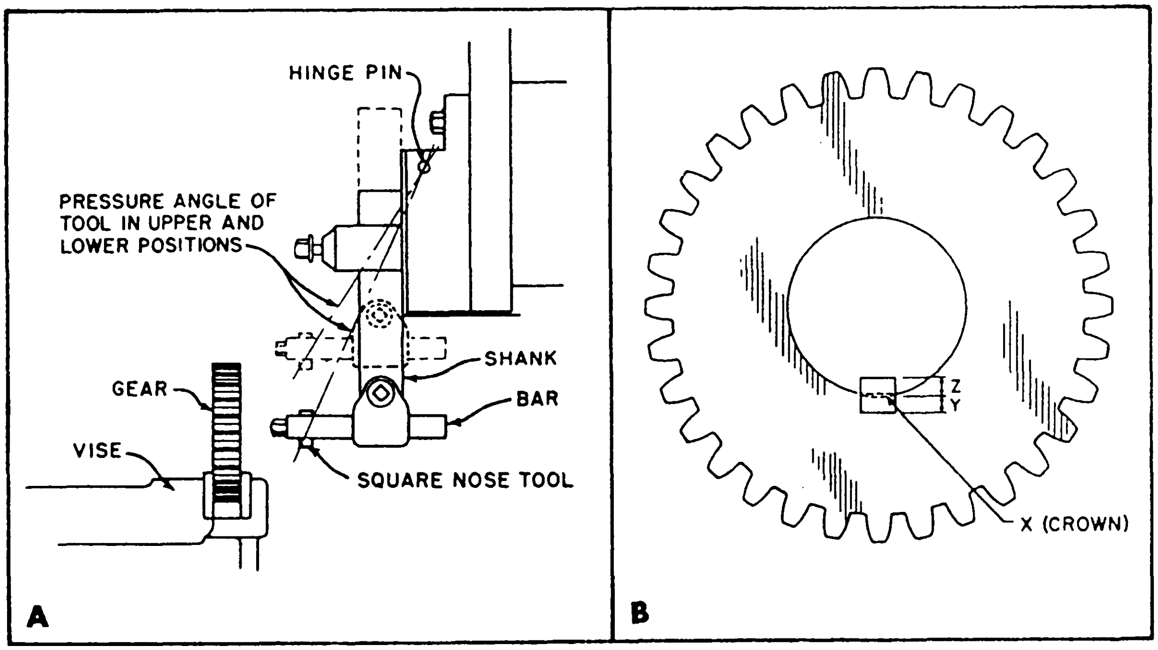

Figure 9-10.—Internal keyway: A. Shaping an internal keyway in a gear. B. Depth of keyways.

1. Lay out the centerline, the keyway width, and the clearance hole centers, as shown in view A of figure 9-9. Drill the clearance holes.

2. Position the shaft in the shaper vise or on the worktable so that it is parallel to the ram. Use a machinist's square to check the centerline on the end of the shaft to be sure it is perpendicular to the surface of the worktable. This ensures that the keyway layout is exactly centered at the uppermost height of the shaft and that the keyway is centered on the centerlines of the shaft.

3. Adjust the stroke and the position of the ram so the forward stroke of the cutting tool ends at the center of the clearance hole. (If you are cutting a blind keyway, be sure the cutting tool has enough clearance at the end of the return stroke so the tool will remain in the keyway slot.) (See view B of fig. 9-9.)

4. Position the work under the cutting tool so that the tool's center is aligned with the centerline of the keyway. (If the keyway is more than 1/2 inch wide, cut a slot down the center and shave each side of the slot until you get the proper width.

5. Start the shaper and use the toolhead slide to feed the tool down to the depth required, as shown on the graduated collar.

SHAPING AN INTERNAL KEYWAY.—To cut an internal keyway in a gear, you will have to use extension tools. These tools lack the rigidity of external tools, and the cutting point will tend to spring away from the work unless you take steps to compensate. The keyway **MUST** be in line with the axis of the gear. Test the alignment with a dial indicator by taking a reading across the face of the gear. Swivel the vise slightly to correct the alignment if necessary.

The bar of the square-nose toolholder should not extend further than necessary from the shank; otherwise, the bar will have too much spring and will allow the tool to be forced out of the cut.

The extension toolholder should extend as far as practical below the clapper block, rather than in the position shown by the dotted lines in view A of figure 9-10. The pressure angle associated with the toolholder in the upper position may cause the pressure of the cut to open the clapper block slightly and allow the tool to leave the cut. In the lower position, the pressure angle is nearly vertical and prevents the clapper block from opening. Another method to prevent the clapper block from opening is to mount the tool in an inverted position.

With the cutting tool set up as in view A of figure 9-10, center the tool within the layout lines in the usual manner, and make the cut to the proper depth while feeding the toolhead down by hand. If you mount the tool in an inverted position, center the tool within the layout lines at the top of the hole, and make the cut by feeding the toolhead upward.

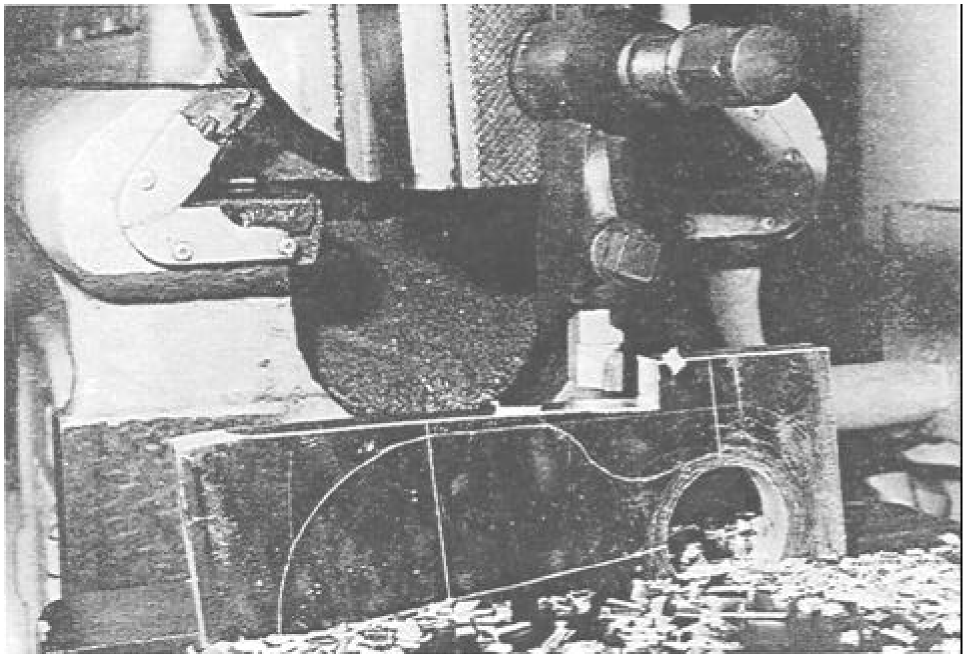

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Figure 9-11.—Shaping irregular surfaces.

Figure 9-10, view B, shows the relative depths to which external and internal keyways are cut to produce the greatest strength. When you cut a keyway in the gear, set the downfeed micrometer collar to zero at the point where the cutting tool first touches the edge of the hole. First, remove the crown, X, from the shaft to produce a flat whose width is equal to the width of the key. Then, make a cut in the shaft to depth 2. The distance of Y plus Z is equal to the height of the key that is to lock the two parts together.

SHAPING IRREGULAR SURFACES.—To machine irregular surfaces, use form ground tools and feed the cutting tool vertically by hand while using power feed to move the work horizontally. A gear rack is an example of work you might shape by using form tools. You can use the toolhead feed to shape work such as concave and convex surfaces. When you machine irregular surfaces, you have to pay close attention because you control the cutting tool manually. Also, you should lay out the job before you machine it to provide reference lines. You also should take roughing cuts to remove excess material to within 1/16 inch of the layout lines.

You can cut **RACK TEETH** on a shaper as well as on a planer or a milling machine. During the machining operation, you may either hold the work in the vise or clamp it directly to the worktable. After you mount and position the work, use a roughing tool to rough out the tooth space in the form of a plain rectangular groove, then finish it with a tool ground to the tooth's finished contour and size.

To machine a rack, use the following sequence of operations:

1. Clamp the work in the vise or to the table.
2. Position a squaring tool, which is narrower than the required tooth space, so the tool is centered on the first tooth space to be cut.
3. Set the graduated dial on the crossfeed screw to zero, and use it as a guide to space the teeth.
4. Move the toolslide down until the tool just touches the work, and lock the graduated collar on the toolslide feed screw.
5. Start the machine and feed the toolslide down slightly less than the whole depth of the tooth, using the graduated collar as a guide, and rough out the first tooth space.
6. Raise the tool to clear the work and move the crossfeed a distance equal to the linear pitch of the rack tooth by turning the crossfeed lever. Rough out the second tooth space, and repeat this operation until all spaces are roughed out.

7. Replace the roughing tool with a tool ground to size for the desired tooth form, and align the tool.

8. Adjust the work so the tool is properly aligned with the first tooth space that you rough cut.

9. Set the graduated dial on the crossfeed screw at zero and use it as a guide to space the teeth.

10. Move the toolslide down until the tool just touches the work, and lock the graduated collar on the toolslide feed screw.

11. Feed the toolslide down the whole depth of the tooth, using the graduated collar as a guide, and finish the first tooth space.

12. Raise the tool to clear the work and move the crossfeed a distance equal to the linear pitch of the rack tooth by turning the crossfeed lever.

13. Finish the second tooth space; then measure the thickness of the tooth with the gear tooth vernier caliper. Adjust the toolslide to compensate for any variation indicated by this measurement.

14. Repeat the process of indexing and cutting until you have finished all of the teeth.

Use the following procedure to machine irregular surfaces that have **CONVEX** and/or **CONCAVE** radii. On one end of the work, lay out the contour of the finished job. When you shape to a scribed line, as shown in figure 9-11, it is good practice to rough cut to within 1/16 inch of the line. You can do this by making a series of horizontal cuts using automatic feed and removing excess stock. Use a left-hand cutting tool to remove stock on the right side of the work and a right-hand cutting tool to remove stock on the left side of the work When 1/16 inch of metal remains above the scribed line, take a file and bevel the edge to the line. This will eliminate tearing of the line by the breaking of the chip. Starting at the right-hand side of the work, set the automatic feed so the horizontal travel is rather slow. Feed the tool vertically by hand to take finishing cuts and produce a smooth contoured surface.

VERTICAL SHAPERS

The vertical shaper (slotter), shown in figure 9-12, is especially adapted to slot internal holes or keyways with angles up to 10°. The vertical ram (fig. 9-12) reciprocates up and down. To do angular slotting, tilt the ram to the required angle. Different models of machines will have their control levers in different locations, but all of them will have the same basic functions and capabilities. The speed of the ram is adjustable to allow for the various materials and machining requirements. Speed is expressed in either strokes per minute or feet per minute, depending on the particular model. You also may adjust the length and the position of the ram stroke. Automatic feed for the cross and longitudinal movements, and on some models the rotary movement, is provided by a ratchet mechanism, gear box, or variable speed hydraulic system. Again, the method depends on the model. You may hold the work in a vise mounted on the rotary table, clamp it directly to the rotary table, or hold it by special fixtures. The square hole in the center of a valve handwheel is an example of work that can be done on a machine of this type. The sides of the hole are cut on a slight angle to match the angled sides of the square on the valve stem. If this hole were cut by using a broach or an angular (square) hole drill, the square would wear prematurely due to the reduced area of contact between the straight and angular surfaces.

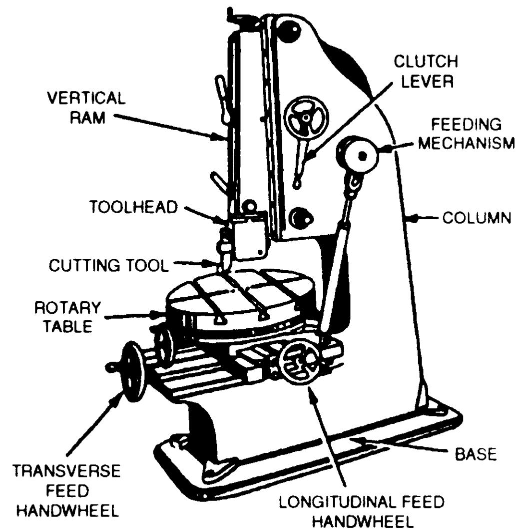

Figure 9-12.—Vertical shaper.

PLANERS

Planers are rigidly constructed machines, particularly suitable for machining long cuts on large and heavy work In general, planers and shapers can be used for similar operations. However, the reciprocating motion of planers is provided by the worktable (platen), while the cutting tool is fed at a right angle to this motion. Like the shaper, the planer cuts only on the forward stroke, after which the table makes a quick return to bring the work into position for the next cut.

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Figure 9-13.—Open side planer.

The size of a planer is determined by the size of the largest work that can be clamped and machined on its table; thus, a 30 inch by 30 inch by 6 foot planer is one that can accommodate work up to these dimensions.

Planers arc divided into two general classes, the **OPEN** side type and the **DOUBLE HOUSING** type.

Planers of the open side type (fig. 9-13) have a single vertical housing to which the crossrail is attached. The advantage of this design is that you can plane work that is too wide to pass between the uprights of a double housing machine.

In the double housing plancr, the worktable moves between two vertical housings to which a crossrail and toolhead are attached. The larger machines are usually equipped with the cutting heads mounted to the crossrail as well as a side head mounted on each housing. With this setup, it is possible to machine simultaneously both the side and the top surfaces of work mounted on the table.

MAJOR COMPONENTS

All planers consist of five principal parts: the bed, table, columns, crossrail, and toolhead.

The bed is a heavy, rigid casting that supports the entire piece of machinery. The ways on which the planer table rides are on the upper surface of the bed.

The table is a flat, cast-iron surface to which the work is mounted. The planer table has T-slots and reamed holes that are used to fasten work to the table. On the underside of the table there is usually a gear train or a hydraulic mechanism that gives the table its reciprocating motion.

The columns of a double housing planer are attached to either side of the bed and at one end of the planer. On the open side planer there is only one column or housing attached on one side of the bed. The columns support and carry the crossrail.

The crossrail serves as the rigid support for the toolheads. The vertical and horizontal feed screws on the crossrail are used to adjust the machine for work of various sizes.

The toolhead is similar to that of the shaper in construction and operation.

All sliding surfaces subject to wear are provided with adjustments. Keep the gibes adjusted to take up any looseness due to wear.

OPERATING THE PLANER

Before you operate a planer, be sure you know where the various controls are and what function each controls. Once you master one model or type of planer, you will have little difficulty with others. However, always look in the manufacturer's technical manual for specific operating instructions on the machine you are using. The following sections contain general information on planer operation.

Table Speeds

The table speeds are controlled by the start-stop lever and the flow control lever (fig. 9-13). Two ranges of speeds and a variation of speeds within each range are available. Use the start-stop lever to select the speed range (LOW-MAXIMUM CUT or HIGH-MINIMUM CUT), and use the flow control lever to vary the speeds within each range. As the flow control lever is moved toward the right, the table speed will gradually increase until it reaches the highest possible speed.

Use the **LOW** speed range to shape hard materials that require high cutting force at low speeds. Use the **HIGH** range for softer materials that require less cutting force but higher cutting speeds.

The **RETURN** speed control provides two return speed ranges (NORMAL and FAST). In **NORMAL,** the return speed varies in ratio with the cutting speed selected. In **FAST,** the return speed remains constant (full speed), independent of the cutting speed setting.

Feeds

Adjust the feed by turning the handwheel that controls the amount of toolhead feed. Turn it counterclockwise to increase the feed. You can read the amount of feed on the graduated dials at the operator's end of the crossrail feed box. Each graduation indicates a movement of 0.001 inch.

To control the toolhead's direction of feed (right or left, up or down), use the lever on the rear of the feed box. To engage or disengage the vertical feed, use the upper of the two levers on the front of the feed box. To give a downward feed to the toolhead, shift the rear, or directional, lever to the down position and engage the clutch lever by pressing it downward. To give an uoward feed, shift the directional lever to the up position.

Use the lower clutch lever on the front of the feed box to engage the horizontal feed of the toolhead. When the directional lever on the rear of the box is in the down position, the head is fed toward the left. When it is in the up position, the head is fed toward the right.

Use the ball crank on top of the vertical slide (toolhead feed) to hand feed the toolslide up or down. A graduated dial directly below the crank indicates the amount of travel.

Use the two square-ended shafts at the end of the crossrail to move the toolhead by hand. To use either of the shafts, put a handcrank on the square end, ensure that the directional lever on the rear of the feedbox is in the center, or neutral, position, and then turn the shaft. The upper shaft controls vertical movement. The lower shaft controls horizontal movement.

Use lock screws on both the cross-slide saddle and the vertical slide to lock these slides in position after you make the tool setting.

The planer side head has powered vertical feed and hand-operated horizontal feed. Use a lever on the rear of the side head feed box to control the vertical feed, both engagement and direction. Control vertical traverse by turning the square shaft that projects from the end of the feed box. Use the bell crank at the end of the toolhead slide to control horizontal movement, both feed and traverse.

Rail Elevation

To raise or lower the crossrail, use the handcrank on the squared shaft projecting from the rear of the rail brace. To move the rail, first loosen the two clamp nuts at the rear of the column and the two at the front; then use the handcrank to move the rail to the desired height. Be sure to tighten the clamp nuts before you do any machining.

On machines that have power rail elevation, a motor is mounted within the rail brace and connected to the elevating mechanism. Rush buttons control the motor's forward and reverse operation. The clamp nuts described in the previous paragraph have the same use on all machines whether they use manual or power elevation.

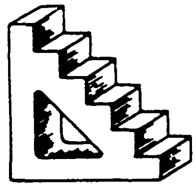

Figure 9-14.—Step block.

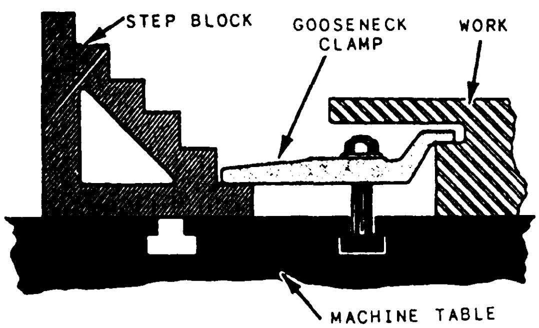

Figure 9-15.—Application of step block and clamp.

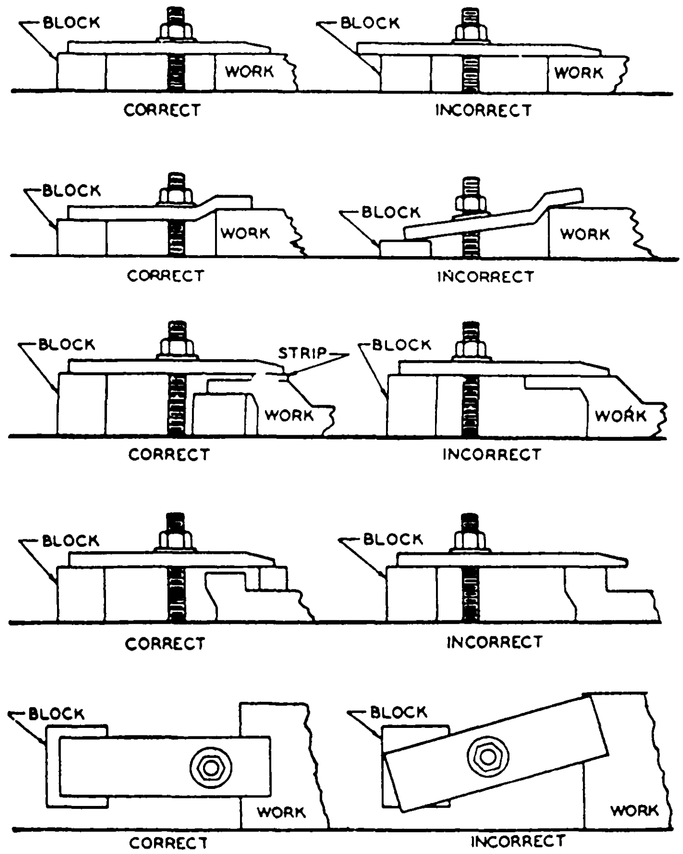

Figure 9-16.—Correct and incorrect clamp applications.

Holding the Work

The various accessories used to hold planer or shaper work may make the difference between a superior job and a poor job. There are no set rules on the use of planer accessories to clamp down a piece of work—results will depend on your ingenuity and experience.

One way to hold down work on the worktable is by using clamps atached to the worktable by bolts inserted in the T-slots. Figure 9-14 shows a step block that you can use with clamps when you need to clamp an irregularly shaped piece of work to the planer table. One way to do this is illustrated in figure 9-15; where an accurately machined step block is used with a gooseneck clamp. Figure 9-16 illustrates correct and incorrect ways to apply clamps.

You can use jacks of different sizes to level and support work on the planer table. The conical point screw (fig. 9-17, B) replaces the swivel pad-type screw for use in a comer. You can use extension bases (fig. 9-17, C, D, E, and F) to increase the effective height of the jack

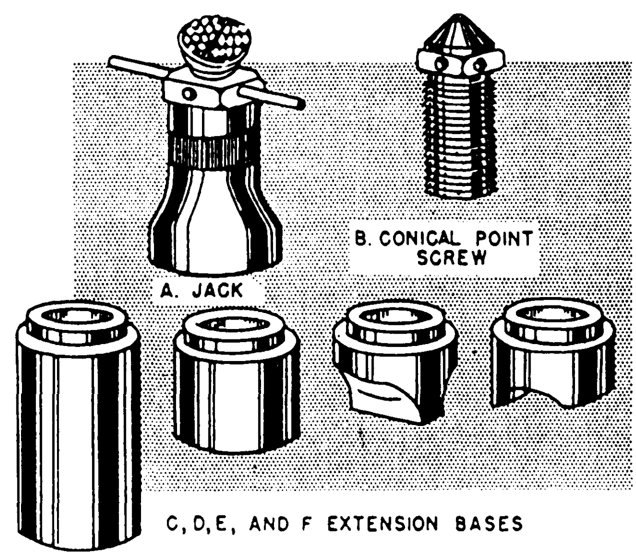

Figure 9-17.—Planer jack and extension bases.

PANTOGRAPHS

The pantograph (engraving machine) is essentially a reproduction machine. It is used in the Navy to engrave letters and numbers on label plates, to engrave and graduate dials and collars, and in other work that requires the exact reproduction of a flat pattern on the workpiece. You can use it to engrave flat and uniformly curved surfaces.

There are several different models of engraving machines that you may have to operate. Figure 9-18 shows one model that mounts on a bench or a table top

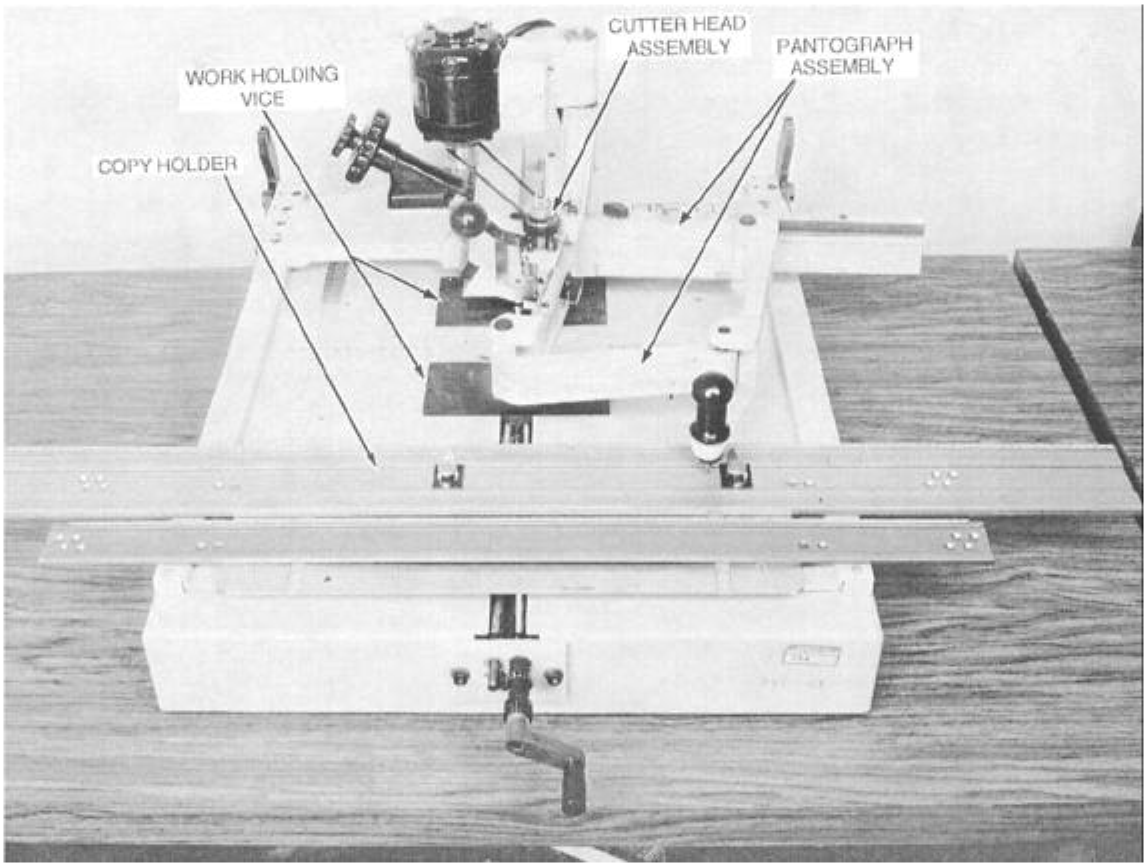

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Figure 9-18.—Engraving machine.

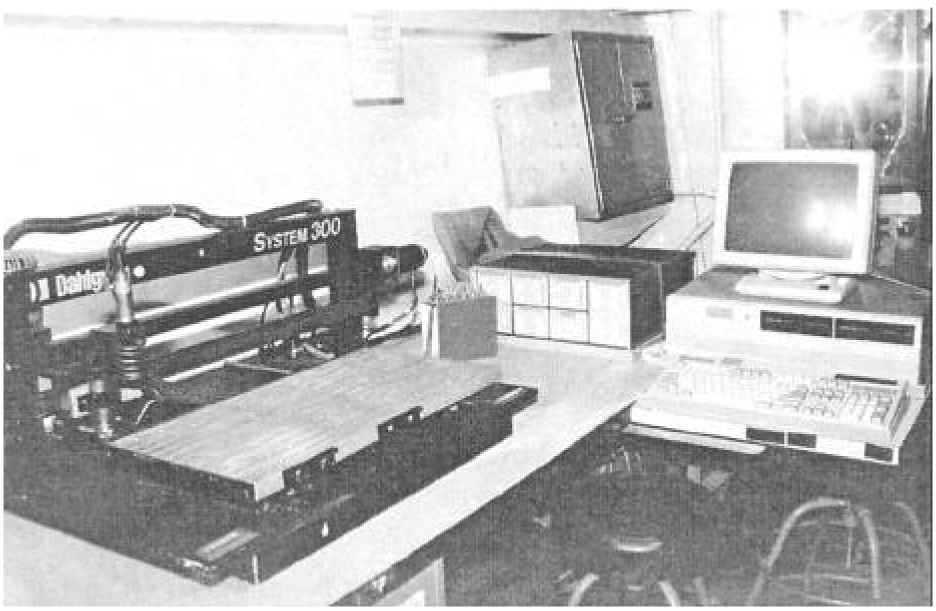

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Figure 9-19.—Computer-controlled engraving machine.

and is used primarily to engrave small items. This particular machine is manufactured by the New Hermes Inc. It's ratio settings range from 2 to 8. That means the largest finished engraving pattern you can produce from a given master will be one-half the size of the original master character.

Figure 9-19 shows a computer-controlled engraving machine. There are several softwear packages available for it. You can do anything from regular engraving to engravings of images produced on the computer screen. Once you learn to operate this machine, you will be able to complete jobs at a much faster pace than you did with a manual engraving machine.

Most computer-controlled engraving machines are on tenders and at shore repair facilities. We will not discuss setup and training on those machines because it is included in the purchase price and provided by the manufacturer. However, nearly all Navy ships have an engraving machine similar to the one shown in figure 9-18. You will need training on it, so we will discuss it in detail.

MAJOR COMPONENTS

The pantograph engraving machine, shown in figure 9-18, consists of four principal parts: pantograph assembly, cutterhead assembly, worktable, and copyholder. We will discuss these parts in the following paragraphs:

1. PANTOGRAPH ASSEMBLY: The pantograph assembly (fig. 9-18) consists of moveable bars used to set the reduction and to hold the stylus and cutterhead. The relationship between movement of the stylus point and movement of the cutter is governed by the relative positions of where the bars and the cutter are set.

2. CUTTERHEAD ASSEMBLY: The cutterhead assembly (fig. 9-18) houses the precision cutter spindle. You can adjust spindle speeds by changing the pulley drives located between the motor and the spindle. There is a vertical feed lever at the head of the cutter. It provides a range of limited vertical movement from 1/16 inch to 1/4 inch to prevent the cutter from breaking when it feeds into work. A plunger locks the spindle for flat surface engraving or releases it for floating vertical movement of 1/2 inch with the forming guide on curved work. The cutterhead assembly is hinged to permit spindle removal from the side. This makes it unnecessary to disturb any work by lowering the table.

3. WORKHOLDING VISE: The workholding vice shown in figure 9-18 is used to hold flat material or nametags. For odd-shaped jobs, there are several fixtures available that mount to the machine base. You can buy these fixtures from your machine's manufacturer.

4. COPYHOLDER: The copyholder shown in figure 9-18 is a dovetailed slot used to hold the master characters commonly known as copy.

SETTING COPY

Lettering used with an engraver is known by various terms, but the Navy uses the term copy to designate the characters used as sample guides. Copy applies specifically to the standard brass letters, or type, that are set in the copyholder of the machine and guide the pantograph in reproducing that copy. Shapes, as distinguished from characters, are called templates or masters.

Copy is not self-spacing; therefore, you should adjust the spaces between the characters by inserting suitable blank spacers furnished with each set of copy. Each line, when set in the copyholder, should be held firmly between clamps.

After setting up the copy in the holder, and before engraving, be sure that the holder is firmly set against the stop screws in the copyholder base. This ensures that the holder is square with the table. Do not disturb these stops; they were properly adjusted at the factory, and any change will throw the copyholder out of square with the table. The worktable T-slots are parallel with the table's front edge, making it easy to set the work and the copy parallel to each other.

SETTING THE PANTOGRAPH

The correct setting of the pantograph is determined from the ratio of (1) the size of the work to the size of the copy layout, or (2) the desired size of engraved characters to the size of the copy characters. This ratio is called a reduction. As we stated before a 2 to 1 reduction results in an engraved layout one-half the size of the master character; an 8 to 1 reduction results in an engraved layout one-eighth the size of the master character.

If a length of copy is 10 inches and the length of the finished job is to be 2 inches, divide the length of the job into the length of the copy:

$$10 \div 2 = 5 \text{ inches}$$

For this job, set the scales (fig. 9-18) at 5.

If the length of the copy is 11 inches and the length of the finished job is to be 4 inches, the reduction is

$$11 \div 4 = 2.75$$

After you have set a reduction, check the pantograph. First, place a point into the spindle; then raise the table until the point barely clears the table. Next, trace along an edge of a copy slot in the copyholder with the tracing stylus. If the cutter point follows parallel to the workholding vise, the reduction is proper. If the point forms an arc or an angle, recalculate the setting and reset the machine.

Table 9-2.—Cutter Speeds

Materials and Feeds	Cutter diameter (at cutting point) 1/32"	1/16"	1/8"	3/16"	1/4"	5/16"	3/8"	7/16"	1/2"
	Speeds (rpm)								
Hardwood (650-800 ft./min.)----	10,000 to 20,000	10,000 to 20,000	10,000 to 20,000	10,000 to 20,000	10,000 to 20,000	9,000	8,000	7,000	6,000
*Bakelite (170-250 ft./min.)----	10,000	8,000	6,000	4,000	3,000	2,200	1,800	1,500	1,300
**Engraver's brass and aluminum (375-425 ft./min.)	10,000 to 15,000	10,000 to 15,000	10,000 to 15,000	8,000	6,000	5,000	4,000	3,500	3,000
Cast iron (130-250 ft./min.)----	8,000	7,500	5,500	3,500	2,500	2,000	1,650	1,400	1,200
Hard bronze and machine steel (80-200 ft./min.)	7,000	6,000	3,000	2,200	1,600	1,200	975	800	700
Annealed tool steel (70-100 ft./min.)	5,000	4,500	2,300	1,600	1,200	1,000	850	725	600
Stainless steel, Monel (45-75 ft./min.)	3,500	2,750	1,400	1,050	700	575	500	435	350
Very hard die and alloy steels (30-45 ft./min.)	2,000	1,250	800	600	475	400	350	300	250

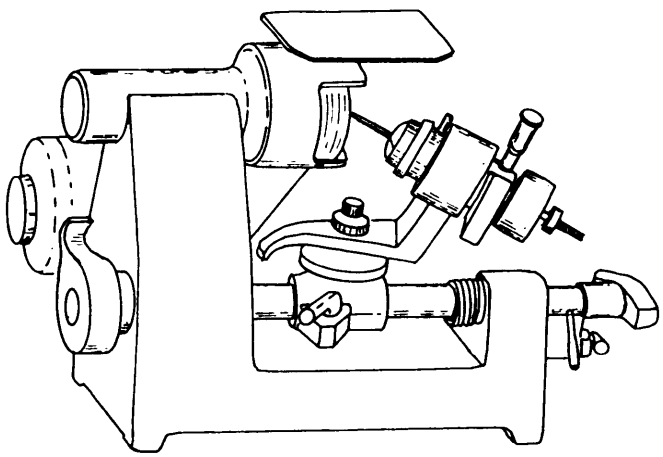

Figure 9-20.—Cutter grinder.

CUTTER SPEEDS

The speeds listed in table 9-2 represent typical speeds for given materials when you are using a high-speed steel cutter. If you are using a carbide cutter, refer to your operators manual for the correct speeds. When using table 9-2, keep in mind that the speeds recommended will vary greatly with the depth of cut, and particularly with the rate at which you feed the cutter through the work.

Run the cutters at the highest speeds possible without burning them, and remove stock with several light, fast cuts rather than one heavy, slow cut. When you cut steel and other hard materials, start with a slow speed and work up to the fastest speed the cutter will stand without losing its cutting edge. Sometimes you may have to sacrifice cutter life to obtain the smoother finish possible at higher speeds. With experience you will know when the cutter is running at its maximum efficiency.

GRINDING CUTTERS

Improper grinding of cutters causes most of the problems in using very small cutters on small lettering. The cutter point must be accurately sharpened. Problems usually occur because the point is burned, the flat is either too high or too low, or perhaps the clearance does not run all the way to the point. Stone off the flat with a small, tine oilstone to make the cutting edge keener.

The cutter grinder shown in figure 9-20 is equipped with interchangeable grinding wheels for carbide and high-speed steel cutters. We will discuss grinding-high

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Figure 9-21.—Position of diamond for truing a grinding wheel.

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Figure 9-22.—Grinding a conical point. A. Cutter angle. B. Rough and finished conical shape.

speed cutters. Refer to your machine manufacturer's manual for information on the operation of your grinder and the angles for carbide cutters.

Grinding Single-Flute Cutters

Before you begin grinding, true up the grinding wheel with the diamond tool supplied with the grinder. Insert the diamond and set the toolhead at approximately the same relation to the wheel, as shown in figure 9-21. Then, swing the diamond across the face of the wheel by rocking the toolhead in much the same manner as you do when grinding a cutter. Your maximum cut should be 0.001 to 0.002 inch. If the diamond fails to cut freely, turn it slightly in the toolhead to present an unused portion of the diamond to the wheel.

ROUGH AND FINISH GRINDING A CONICAL POINT.—Set the grinder toolhead to the desired cutting edge angle (fig. 9-22, view A). This angle usually varies from 30° to 45° depending on the work desired. Use a 30° angle for most sunken letter or design engraving on metal or bakelite plates. Now place the cutter in the toolhead and rough grind it to approximate size by swinging it across the wheel's face. Do not rotate the cutter while it is in contact with the face of the wheel, but swing it straight across, turning it slightly **BEFORE** or **AFTER** it makes contact with the wheel. This will produce a series of flats, as in the rough shape shown in figure 9-22, view B. Now feed the cutter

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Figure 9-23.—Grinding the flat. A. Flat not ground to center. B. Flat ground to center.

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Figure 9-24.—First operation in grinding clearance.

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Figure 9-25.—A tipped off cutter.

into the wheel and rotate it at the same time to grind off the flats and produce a smooth cone. The finished cone should look like the finished conical shape in figure 9-22, view B, smooth and entirely free of wheel marks.

GRINDING THE FLAT TO CENTER.—The next operation is to grind the flat to center. For very small, delicate work it is absolutely essential to grind this flat **EXACTLY** to center. If the flat is oversize, you

Table 9-3.—Rake Angles for Single-Flute Cutters

Material to be cut	Angle B (See figs. 12-27) and 12-28)
Tool steel	5-10 degrees
Machine steel	10-15 degrees
Hard brass	15-20 degrees
Aluminum	20-25 degrees
Bakelite, celluloid, wood, fiber	20-25 degrees

can readily see it after grinding the cone, and the point will appear as shown in figure 9-23, view A and the left side of view B. To correct this, grind the flat to center as in the right side of view B.

GRINDING THE CHIP CLEARANCE.—The cutter now has the correct angle and a cutting edge, but has no chip clearance. This must be provided to keep the back side of the cutter from rubbing against the work and heating excessively, and to allow the hot chips to fly off readily. The amount of clearance varies with the angle of the cutter. Use the following procedure to grind chip clearance:

In the first step, gently feed the cutter into the face of the wheel. Do not rotate the cutter. Hold the back (round side) of the conical point against the wheel. Rock the cutter continuously across the wheel's face, without turning it, until you grind a flat that runs out exactly at the cutter point (fig. 9-24). Check this very carefully, with a magnifying glass if necessary, to be sure you have reached the point with this flat. Be extremely careful not to go beyond the point.

In the next step, grind away the rest of the stock on the back of the conical side to the angle of the flat, up to the cutting edge. Rotate the conical side against the face of the wheel and remove the stock, as shown in figure 9-22, view B. Be extremely careful not to turn the cutter too far and grind away part of the cutting edge. Clean up all chatter marks. Be careful of the point; this is where the cutting is done. If this point is incorrectly ground, the cutter will not work.

TIPPING OFF THE CUTTER POINT.—To engrave hairline letters up to 0.0005 inch in depth, you should not flatten, or **TIP OFF,** the cutter point. For ordinary work, however, you should flatten this point as much as the work will permit. Otherwise, it is very difficult to retain a keen edge with such a tine point, and when the point wears down, the cutter will immediately fail to cut cleanly. The usual way to tip off is to hold the cutter in your hands at the proper inclination from the grinding wheel face and touch the cutter very lightly against the wheel. You also may dress it with an oilstone. Angle A (fig. 9-25) should be approximately 3°; this angle causes the cutter to bite into the work like a drill when it is fed down. Angle B (fig. 9-25) varies, depending on the material to be engraved. Use table 9-3 as a guide to determine angle B.

Grinding Square-Nose Single-Flute Cutters

A properly ground square-nose single-flute cutter should be similar to the one shown in figure 9-26. When square-nose cutters are ground, they should be tipped off in the same manner as described in connection with figure 9-25. All square-nose cutters have their peripheral clearances ground back of the cutting edge. After grinding the flat to center (easily checked with a micrometer), grind the clearance by feeding the cutter in the required amount toward the wheel and turning the cutter until you have removed all stock from the back

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Figure 9-26.—Square-nose cutter with a properly ground tip.

Table 9-4.—Chip Clearance Table for Square-Nose Cutters

Cutter diameter	Clearance	Cutter diameter	Clearance
Inches	Inches	Inches	Inches
1/10	.004	1/4	.010
1/8	.006	5/16	.012
5/32	.006	3/8	.015
3/16	.008	7/16	.015
		1/2	.020

Table 9-5.—Clearance Angles for Three- and Four-Sided Cutters

Degrees of cutting.......	45°	40°	35°	30°	25°	20°	15°	10°	5°
Angle of clearance: (Degrees)									
3 sides.............	26 1/2	23	19 1/2	16	13	10 1/2	7 1/2	5	2 1/2
4 sides.............	35 1/2	23	25 1/2	22 1/2	18 1/2	14 1/2	10	7	3 1/2

(round side), up to the cutting edge. Table 9-4 provides information on chip clearance for various sized cutters.

Grinding Three- and Four-Sided Cutters

Three- and four-sided cutters (see fig. 9-27) are used to cut small steel stamps and to engrave small engraving where a very smooth finish is desired. The index plate on the toolhead collet spindle has numbered index holes for indexing to grind three- and four-sided cutters, as explained in the next paragraph.

Set the toolhead for the desired angle. Plug the pin in the index hole for the desired number of divisions and grind the flats. Now, without loosening the cutter in the toolhead collet, reset the toolhead to the proper clearance angle. Clearance angles are listed in table 9-5.

PANTOGRAPH ATTACHMENTS

Some attachments commonly used with the pantograph are copy dial holders, indexing attachments, forming guides, and rotary tables. These attachments extend the capabilities of the pantograph from flat, straight line engraving to include circular work, cylindrical work, and indexing.

When you use a circular copy plate, you may use the copy dial holder, shown in figure 9-28, instead of the regular copyholder. This holder has a spring-loaded indexing pawl, which is aligned with the center pivot hole. This pawl engages in the notches in a circular copy plate to hold the plate in the position required to engrave the character.

You may use an indexing attachment, such as that shown in figure 9-29, to hold cylindrical work to be graduated. In some cases, the dividing head (used on the milling machine) is used for this purpose. The work to

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Figure 9-27.—Three-sided cutter.

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Figure 9-28.—Copy dial holder and plate.

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Figure 9-29.—Using an indexing attachment.

be engraved is held in this attachment and may be indexed for any number of divisions available on the plate. Figure 9-29 shows a micrometer collar being held for graduation and engraving.

You will use a forming guide (sometimes called a radius plate) to engrave cylindrical surfaces. The contour of the guide must be the exact opposite of the work; if the work is concave the guide must be convex and vice versa. Mount the forming guide on the forming bar. (See fig. 9-29.) When the spindle floating mechanism is released, the spindle follows the contour of the forming guide.

Use the rotary table shown in figure 9-30 to hold work such as face dials. It is similar to the rotary table used on milling machines. It is mounted directly on the

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Figure 9-30.—A rotary table.

worktable and provides a means of rapid graduation and of engraving the faces of disks.

USING A CIRCULAR COPY PLATE

You should be able to use a circular copy plate efficiently to engrave several similar workpieces with single characters used consecutively. For example, you can use the following setup to engrave 26 similar workpieces with a single letter, but with each piece having a different letter.

1. Set the workpiece conveniently on the worktable and clamp two aligning stops in place. Do not remove these stops until the entire job is completed.

2. Set the circular plate on the copyholder so that the plate can be rotated by hand. Check to ensure that the indexing pawl engages the notch on the rim so the plate will be steady while you trace each character.

3. Set the machine for the required reduction and speed, and adjust the worktable so the spindle is in position over the workpiece.

4. Clamp the first workpiece in place on the worktable. (The aligning stops, step 1, ensure accurate positioning.)

5. Rotate the circular plate until the letter *A* is under the tracing stylus and the index pawl is engaged in the notch.

6. Engrave the first piece with the letter *A*. Check the operation for required adjustments of the machine.

7. After you have finished the first piece, remove it from the machine. Do not change the alignment of the aligning stops (step 1), the worktable, or the copyholder. Place the second workpiece in the machine. Index the circular plate to the next letter and repeat the process.

8. Continue to load the workpieces, index the plate to the next character, engrave, and remove the work until you have finished the job.

ENGRAVING A GRADUATED COLLAR

To engrave a graduated collar, as shown in figure 9-29, use a forming guide and indexing attachment. You also can use the circular copy plate to speed up the numbering process. After you engrave each graduation, index the work to the next division until you finish the graduating. When you engrave numbers with more than one digit, offset the work angularly by rotating the work so the numbers are centered on the required graduation marks.

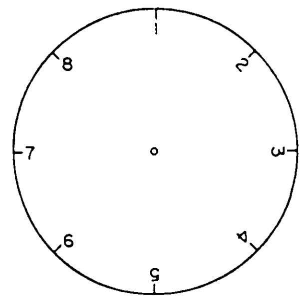

Figure 9-31.—A dial face.

ENGRAVING A DIAL FACE

Use a rotary table and a circular copy plate to engrave a dial face, such as the one shown in figure 9-31. Note that the figures on the right side of the dial are oriented differently from those on the left side; this illustrates the usual method of positioning characters on dials. The graduations are radially extended from the center of the face. The graduations also divide the dial into eight equal divisions.

Use the following procedures to set up and engrave a dial face:

1. Set the reduction required. Use the size of the copy on the circular copy plate and the desired size of the numerals on the work as the basis to compute the reduction.

2. Set the copy plate on the copyholder and be sure it is free to rotate when the ratchet is disengaged.

3. Mount a rotary table on the worktable of the engraver. Position the dial blank on the rotary table so the center of the dial coincides with the center of the rotary table. Clamp the dial blank to the rotary table.

4. Place the tracing stylus in the center of the circular copy plate and adjust the worktable so the center of the dial is directly under the point of the cutter.

5. Rotate the copy plate until the copy character used to make graduation marks is aligned with the center of the copy plate and the center of the work. Set the stylus in this mark. Now, by feeding the worktable straight in toward the back of the engraver, adjust the table so the cutter will cut the graduation to the desired length.

6. Start the machine and adjust the engraver worktable vertically for the proper depth of cut. Then, clamp the table to prevent misalignment of the work.

Any further movement of the work will be made by the rotary table feed mechanism.

7. Engrave the first graduation mark.

8. Using the rotary table feed wheel, rotate the dial to the proper position for the next graduation. Since there are eight graduations, rotate the table 45°; engrave this mark and continue until the circle is graduated. You will now be back to the starting point.

NOTE: Do not move the circular copy plate during the graduating process.

9. To engrave numbers positioned as shown on the right side of the dial in figure 9-31, move the worktable so the cutter is in position to engrave the numbers. Rotate the circular copy plate to the numeral 1 and engrave it. Rotate the rotary table 45° and the circular copy plate to 2, and engrave it. Continue this process until you have engraved all the numbers. If two- (or more) digit numbers are required, offset the dial as previously described.

10. To engrave the numbers shown on the left side of the dial in figure 9-31, rotate the copy plate to the required number. Then, using the cross feed and longitudinal feed of the engraver table, position the cutter over the work at the point where the number is required. This method requires you to reposition the worktable for each number. As previously stated, movement of the engraver worktable in two directions results in angular misalignment of the character with the radius of the face; in this example, angular misalignment is required.